TRANSLATION

I, Yuko Mitsui, residing at 4-6-10, Higashikoigakubo, Kokubunji-shi, Tokyo, Japan, state:

that I know well both the Japanese and English languages,

that I translated, from Japanese into English, Japanese Patent Application No. 2002-013333, filed on January 22, 2002, and

that the attached English translation is a true and accurate translation to the best of my knowledge and belief.

Dated: May 15, 2006

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Yuko Mitui

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[Title of the Invention]	FUEL ASSEMBLY
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[List of Items Submitted]

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[Necessity of Proof] Necessary

[Document] SPECIFICATION

[Title of the Invention] FUEL ASSEMBLY

[What is claimed is:]

[Claim 1] A fuel assembly characterized by comprising:

a lower nozzle set on a lower core plate of a nuclear reactor with pressurized water;

an upper nozzle with a press spring to urge said lower nozzle against the lower core plate;

a plurality of control rod guide tubes which guide control rods, having passed through said upper nozzle, toward the lower core plate;

a plurality of support grids mounted on said control rod guide tubes;

a plurality of fuel rods held by said support grids to be substantially parallel to said control rod guide tubes;

a thin tube-like dashpot formed on each of said control rod guide tubes to reduce a fall velocity of a corresponding one of the control rods;

a thimble screw which connects each of said control rod guide tubes to said lower nozzle; and

a thimble screw hole formed to extend through said thimble screw, wherein

said dashpot has a large-diameter portion, at a lower portion thereof, with substantially the same diameter as that of each of said control rod guide tubes, and a hole diameter d of said thimble screw hole falls within a range of $0.04D < d < 0.08D$ where D is an inner diameter of the large-diameter

portion.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a fuel assembly used in a nuclear reactor with pressurized water.

[0002]

[Prior Art]

An example of a nuclear reactor with currently widely used for power generation includes a pressurized water nuclear reactor (to be referred to as "PWR" hereinafter). A fuel assembly used therein is generally a canless fuel assembly with no wrapper tube. The structure will be briefly described. Top and lower nozzles each having a plurality of coolant flow holes are connected to each other with a plurality of control rod guide tubes extending parallel to each other.

[0003]

More specifically, the upper ends of the control rod guide tubes, i.e., so-called guide thimbles, are mechanically connected to the upper nozzle, and the lower ends thereof are also mechanically connected to the lower nozzle. These guide thimbles respectively accept the thin elongated control rods of a control rod cluster. Depending on the loading position of the fuel assembly in the core, the guide thimbles do not accept the control rods as they are not located at corresponding positions. In this case, the guide thimbles accept non fuel bearing components such as thimble plugs

or burnable poisons. A plurality of grids are mounted on the guide thimbles. The fuel rods are accepted in the lattice openings and are elastically supported there.

[0004]

Of the structure of the fuel assembly briefly described above, the structure of the connecting portion that connects the guide thimbles and lower nozzle will be described in more detail with reference to FIG. 3 and FIG. 4.

[0005]

Firstly, referring to FIG. 3, inner-threaded lower end plugs 3 are attached to the lower ends of guide thimbles 1 each having hollow shape. These are covered with bottomed cylinders called inserts 5. At the lower nozzle 7 positioned below the guide thimble 1, there is a installation through hole 9 in which a fastening bolt called a thimble screw 11 is inserted.

[0006]

A thimble screw hole 13 is cut and provided in the thimble screw 11, and allows coolant water to flow through during use in a core. There, the screw at the top end part of the thimble screw is screwed on the inner thread of the lower end plug 3, and holding the insert 5 steadily and connecting the lower nozzle 7 and the guide thimble 1. A pin groove is formed at a head part 12 of the thimble screw 11, and a rotation-stopper pin 15 is attached thereto and welded and fixed to the lower nozzle 7.

[0007]

On the other side, a lower support grid 17 is fixed to the insert 5. A counter-boring hole 19 is cut and formed in the lower end part of the thimble screw hole 13, and the rotation-stopper pin 15 does not hinder the flow-through of the coolant water.

[0008]

With this structure, the drain holes 15 of the thimble screws 14 guide the coolant water into the guide thimbles 2 in the core, and the introduced coolant water cools the non fuel bearing components attached thereto. The thimble screw hole 15 also serves as a hole for sending the inner coolant water to the outside.

[0009]

Further, in emergency during operation of the nuclear reactor, the control rods are urgently inserted in the guide thimbles 2 by free fall, and they drain holes 15 also serve as a restrictor for limiting the outlow velocity of the inner coolant so the fall impact is moderated. In other words, to assure the cooling function described above, the larger the diameter d of the thimble screw hole 13, the better. To moderate the fall impact produced when the control rods fall, the smaller the diameter d, the better, which is a contradictory characteristic.

[0010]

When the control rods are urgently inserted in the guide thimbles 2 by free fall at emergency during operation of

the nuclear reactor, an excessively large impact is applied to the upper nozzle 3. For this reason, at the guide thimble 1, a tube-like dashpot part 20 is formed, and this dashpot part 20 reduces the velocity of the control rod falling in the guide thimble 2, thereby moderating the excessively large impact acting on the upper nozzle 3.

[0011]

According to this fuel assembly 1 with such a dashpot part 20, as shown in FIG. 5, a dashpot part 20 with a length of 0.16 to 0.18L is provided along the axial direction of the guide thimble 1 where L is the length of the guide thimble 2. Therefore, the compression load acting in the axial direction of the guide thimble 1 may cause flexural deformation of the dashpot part 20. In this case, insertion of the control rod may be hindered.

[0012]

For this reason, as shown in FIGS. 6 and 7, a technique is disclosed in which the length of the dashpot part 20 of the guide thimble 1 is decreased. With this arrangement, the length of the dashpot part 20 with respect to the length L of the guide thimble 1 can be suppressed to fall within the range of 0.03 to 0.1L, so the flexural rigidity of the dashpot part 20 is increased. This can prevent flexural deformation of the dashpot part 20. Hereinafter, this will be referred to as an improved guide thimble. The lower structure of a fuel assembly to which an improved guide thimble shown in FIG. 6 and FIG. 7 is applied is different

only partly from that of the fuel assembly 1 in the sleeves 10 provided from an intermediate support grid 28 and the lower support grid 17. However, they are substantially equal to each other.

[0013]

[Object of the Invention]

However, the fuel assembly to which this improved guide thimble has the following problems.

[0014]

That is, in the improved guide thimble is applied, the length of the dashpot part 20 on the lower end side of the guide thimble 1 is decreased, as shown in FIGS. 6 and 7. This increases the flexural rigidity of the dashpot part 20 to prevent its flexural deformation. However, a so-called braking effect that moderates the fall velocity of the control rod is decreased.

[0015]

In a nuclear reactor with pressurized water, its fall terminal velocity is limited from the viewpoint of ensuring the safety of the fuel assembly. Originally, the dashpot part 20 is provided along the axial direction of the guide thimble, as shown in FIG. 5, in order to moderate the fall velocity of the control rod such that the fall terminal velocity does not exceed a limit. For this reason, as shown in FIGS. 6 and 7, the fuel assembly employing the improved guide thimble has a problem that a countermeasure that moderates the fall terminal velocity of the control rod must

be provided by another means.

[0016]

The present invention has been made in view of the above situation, and has as its object to provide a fuel assembly in which an improved guide thimble is employed and the diameter of the hole of a thimble screw is adjusted so that a fall impact produced when a control rod falls is moderated, and flexural deformation of a dashpot part is prevented, without impairing the cooling function of non fuel bearing components.

[0017]

[Means for Achieving the Object]

In order to achieve the above object, the present invention has the following means.

[0018]

That is, according to the invention in claim 1, a fuel assembly comprises: a lower nozzle set on a lower core plate of a nuclear reactor with pressurized water; an upper nozzle with a press spring to urge said lower nozzle against the lower core plate; a plurality of control rod guide tubes which guide control rods, having passed through said upper nozzle, toward the lower core plate; a plurality of support grids mounted on said control rod guide tubes; a plurality of fuel rods held by said support grids to be substantially parallel to said control rod guide tubes; a thin tube-like dashpot formed on each of said control rod guide tubes to reduce a fall velocity of a corresponding one of the control rods; a thimble screw which connects each of said control rod

guide tubes to said lower nozzle; and a thimble screw hole formed to extend through said thimble screw, wherein said dashpot has a large-diameter portion, at a lower portion thereof, with substantially the same diameter as that of each of said control rod guide tubes, and a hole diameter d of said thimble screw hole falls within a range of $0.04D < d < 0.08D$ where D is an inner diameter of the large-diameter portion.

[0019]

[Embodiments of the Invention]

The embodiments of the present invention will be described hereinafter with reference to the accompanying drawings.

[0020]

Regarding the reference numerals used to describe the following embodiments, the same reference numerals denote the same portions as those of FIGS. 4 to 8.

[0021]

An embodiment of the present invention will be explained with reference to FIG. 1 to FIG. 3.

[0022]

At first, the entire structure of the fuel assembly 30 according to the embodiment of the present invention will be explained.

[0023]

In an upper nozzle 21, a plurality of coolant flow holes and installation holes for guide thimbles are formed in an end plate, which is a structure like a bottomed box

having a horizontal cross-section is substantially square and is equivalent to a bottom plate. In addition, a press spring 22 is attached to an upper part thereof. A lower nozzle 7 has a top plate part or an end plate having a plan shape which is substantially square, and there, the plurality of coolant flow holes and the installation holes for the guide thimbles are formed. Further, leg parts 23 are respectively projected and formed integrally at four corners on the lower surface of the end plate.

[0024]

These upper nozzle 21 and lower nozzle 7 are respectively connected to the upper ends and lower ends of the plurality of guide thimbles 1 having hollow tube shapes, using the installation holes described above. Fixed to the lower end parts of the guide thimbles 1 are lower end plugs 3, as shown in FIG. 7 and FIG. 8. In this thimble 1, one upper support grid 27 and seven intermediate support grids 28 are attached at intervals, further, in a connection structure of the lower support grid 17. Note that the number of intermediate grids 28 should be considered as being able to be increased or decreased properly.

[0025]

Further, fuel rods 26 are respectively inserted in and supported by grid openings in which the upper grid 27, the intermediate grids 28, and the lower support grid 17 are aligned, thus forming the fuel assembly.

[0026]

Next, the structure of a connection portion between the guide thimbles 1 and the lower nozzles 7 will be explained. In the fuel assembly 30 according to the first embodiment of the present invention, the structure of the connecting portion for connecting its guide thimbles 1 and the lower nozzle 4 is as shown in FIG. 5 and FIG. 7 or FIG. 8, and adopts a so-called improved guide thimble. Further, the inner diameter D of the lower large-diameter portion of the guide thimble 1 and a hole diameter d of a thimble screw hole 13 satisfy the following equation (1):

$$0.04D < d < 0.08D \quad \cdots (1)$$

Next, the function of the fuel assembly according to this embodiment with the above arrangement will be described.

[0027]

FIG. 2 is a graph showing results obtained by measuring a terminal velocity V of a control rod inserted in the guide thimble 1 by free fall in a fuel assembly formed as shown in FIG. 7 and FIG. 8, by using (d/D), which is the ratio of the hole diameter d of the thimble screw hole 13 to the inner diameter D of the lower large-diameter portion of the guide thimble 1, as a parameter.

[0028]

The axis of ordinate indicates (V/V_0) obtained by dividing the terminal velocity V of the control rod inserted in the guide thimble 1 by free fall by a limited terminal velocity V_0 determined from the viewpoint of moderating

the fall impact of the control rod. Specifically, the range of $(V/V_0) < 1$ is a range where the terminal velocity V of the control rod inserted in the guide thimble 1 by free fall can be suppressed to be lower than the limited terminal velocity V_0. The range of $(V/V_0) \geqq 1$ is a range where the terminal velocity V of the control rod inserted in the guide thimble 1 by free fall becomes equal to or more than the limited terminal velocity V_0.

[0029]

As shown in FIG. 2, in the range of $(d/D) < 0.08$, $(V/V_0) < 1$ is established, and the terminal velocity V of the control rod inserted in the guide thimble 1 by free fall does not exceed the limited terminal velocity V_0 but satisfies the design standard. In the range of $(d/D) \geqq 0.08$, $(V/V_0) \geqq 1$ is established, and the terminal velocity V of the control rod inserted in the guide thimble 1 by free fall exceeds the limited terminal velocity V_0 and does not satisfy the design standard.

[0030]

Accordingly, from the viewpoint of the terminal velocity V of the control rod inserted in the guide thimble 2 by free fall, the hole diameter d of the thimble screw hole 13 and the inner diameter D of the lower large-diameter portion of the guide thimble 1 must satisfy $d < 0.08D$.

[0031]

Meanwhile, as described earlier, the thimble screw hole 13 serves to guide the coolant water into the guide

thimble 1 in order to cool the non fuel bearing components. From this viewpoint of assuring the cooling function, the larger the hole diameter d of the thimble screw 13, the better.

[0032]

FIG. 3 is a graph showing results obtained by measuring the cooling ability of the non fuel bearing components in a fuel assembly formed as shown in FIG. 7 and FIG. 8, by using (d/D), which is the ratio of the diameter d of the thimble screw hole 13 to the inner diameter D of the lower large-diameter portion of the guide thimble 2, as a parameter.

[0033]

Note that the axis of ordinate indicates (C/C_0) obtained by dividing a coolant inflow amount C from the thimble screw 11 by a coolant inflow amount C_0 necessary for cooling the non fuel bearing components when (d/D) is used as the parameter. More specifically, in the range of $(C/C_0) \leqq 1$, the coolant inflow amount C does not exceed the necessary coolant inflow amount C_0. In the range of $(C/C_0) > 1$, the coolant inflow amount C exceeds the necessary coolant inflow amount C_0.

[0034]

As shown in FIG. 3, in the range of $(d/D) > 0.04$, $(C/C_0) > 1$ is established, and the coolant inflow amount C becomes larger than the necessary coolant inflow amount C_0. Meanwhile, in the range of $(d/D) \leqq 0.04$, $(C/C_0) \leqq 1$ is established, and the coolant inflow amount C does not exceed the necessary

coolant inflow amount C_0.

[0035]

Accordingly, from the viewpoint of the cooling ability, the hole diameter d of the thimble screw hole 13 and the inner diameter D of the lower large-diameter portion of the guide thimble 1 must satisfy $d > 0.04D$.

[0036]

In the fuel assembly according to this embodiment, an improved guide thimble is employed, and the inner diameter D of the lower large-diameter portion of the guide thimble 1 and the hole diameter d of the thimble screw 13 are adjusted to satisfy $0.04D < d < 0.08D$.

[0037]

Hence, the coolant can be sufficiently supplied also from the viewpoint of assuring the cooling function of the non fuel bearing components. From the viewpoint of moderating the fall impact of the control rod as well, the terminal velocity V of the control rod can be suppressed to be equal to or less than the fall velocity with which the fall impact of the control rod can be moderated. Therefore, flexural deformation of a dashpot part 20 can be prevented.

[0038]

In the above, a preferred embodiment of the present invention has been explained with reference to appended drawings. The present invention, however, is not limited to this structure. Various modifications and corrections will readily occur to those skilled in the art in the scope of

the invented technical ideas in the claims. Therefore, those modifications and corrections may be taken to be within the technical scope of the present invention.

[0039]

[Advantages of the Invention]

As has been explained above, according to the present invention, it is possible to realize a fuel assembly in which an improved guide thimble is employed and the hole diameter of a thimble screw is adjusted so that a fall impact produced when a control rod falls is moderated, and flexural deformation of a dashpot part is prevented, without impairing the cooling function of non fuel bearing components.

[Brief Description of the Drawings]

[FIG. 1]

An entire elevation concerning an embodiment of the present invention;

[FIG. 2]

A graph showing the relationship between (hole diameter d of thimble screw/inner diameter D of lower large-diameter portion of guide thimble) and (fall terminal velocity V of control rod/limited fall terminal velocity V_0 of control rod);

[FIG. 3]

A graph showing the relationship between (thimble screw hole diameter d/inner diameter D of lower large-diameter portion of guide thimble) and (coolant inflow amount C from thimble screw/coolant inflow amount C_0 from thimble screw which is necessary for cooling non fuel bearing components);

[FIG. 4]

A partial elevation showing part of a lower structure of a fuel assembly according to the prior art;

[FIG. 5]

A bottom view corresponding to FIG. 4;

[FIG. 6]

An elevation showing a guide thimble which comprises dashpot parts at two portions;

[FIG. 7]

An elevation showing part of the lower structure of a fuel assembly to which an improved guide thimble is applied; and

[FIG. 8]

An elevation showing part of the lower structure of a fuel assembly to which an improved guide thimble is applied.

[Explanation of Reference Symbols]

d … Hole diameter of thimble screw

C … Coolant inflow amount

Co … Necessary coolant inflow amount

D … Inner diameter of lower large-diameter part of guide thimble

V … Terminal velocity of control rod

Vo … Limited terminal velocity of control rod

1 … Guide thimble

3 … Lower end plug

5 … Insert

7 … Lower nozzle

9 … Through installation hole

10 … Sleeve

11 … Thimble screw

12 … Thimble screw head part

13 … Thimble screw hole

15 … Rotation stopper pin

17 … Lower support grid

19 … Counter-boring hole

20 … Dashpot part

21 … Upper nozzle

22 … Press spring

23 … Leg part

26 … Fuel rod

27 … Upper support rod

28 … Intermediate support rod

30 … Fuel assembly

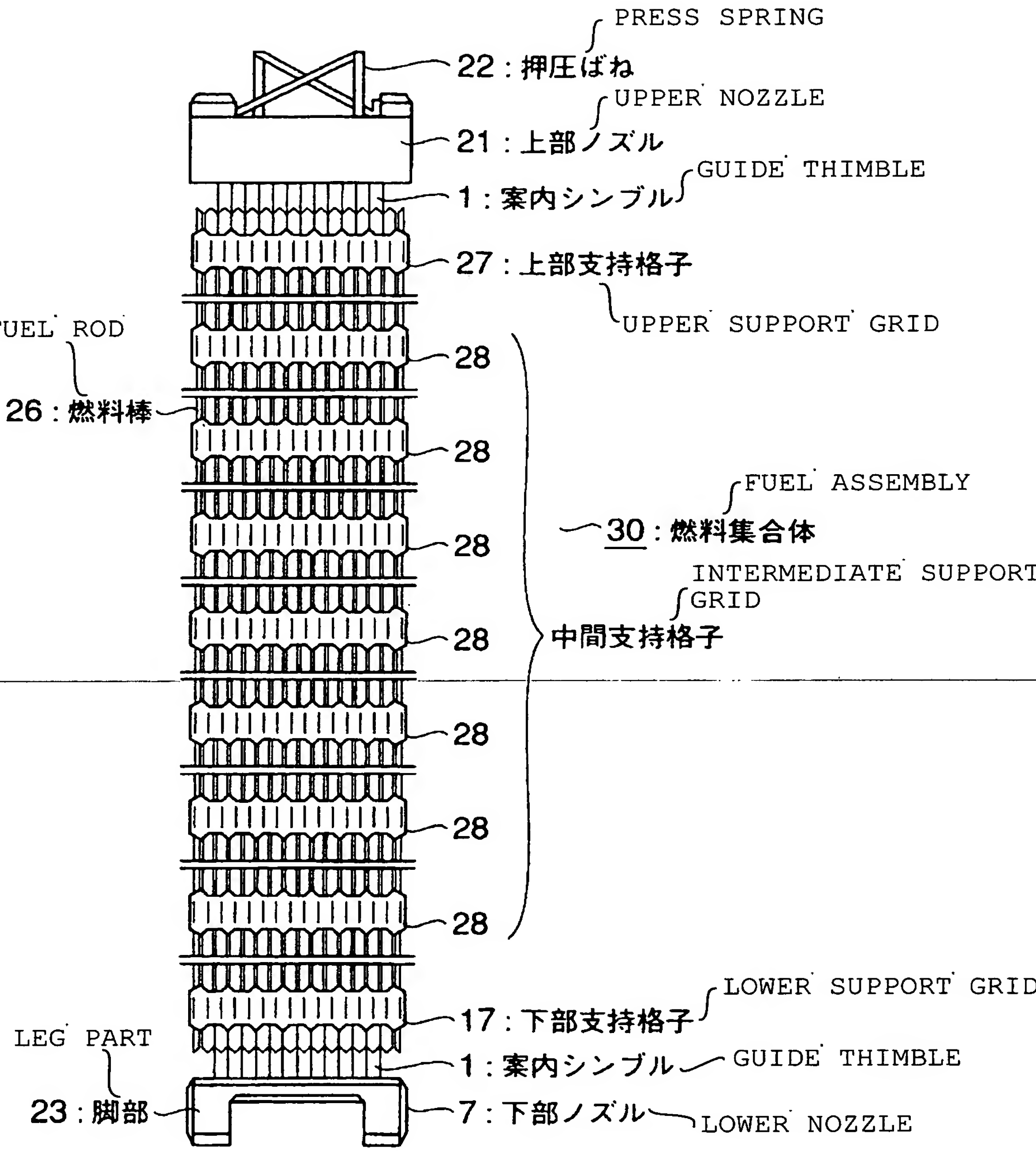
DOCUMENT

【書類名】 図面

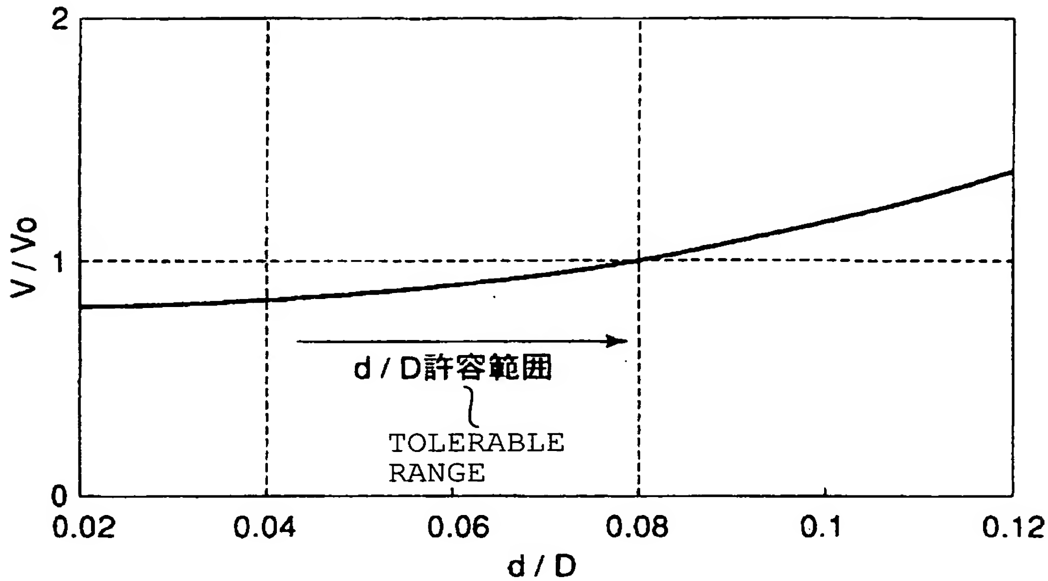
FIGURE

【図１】

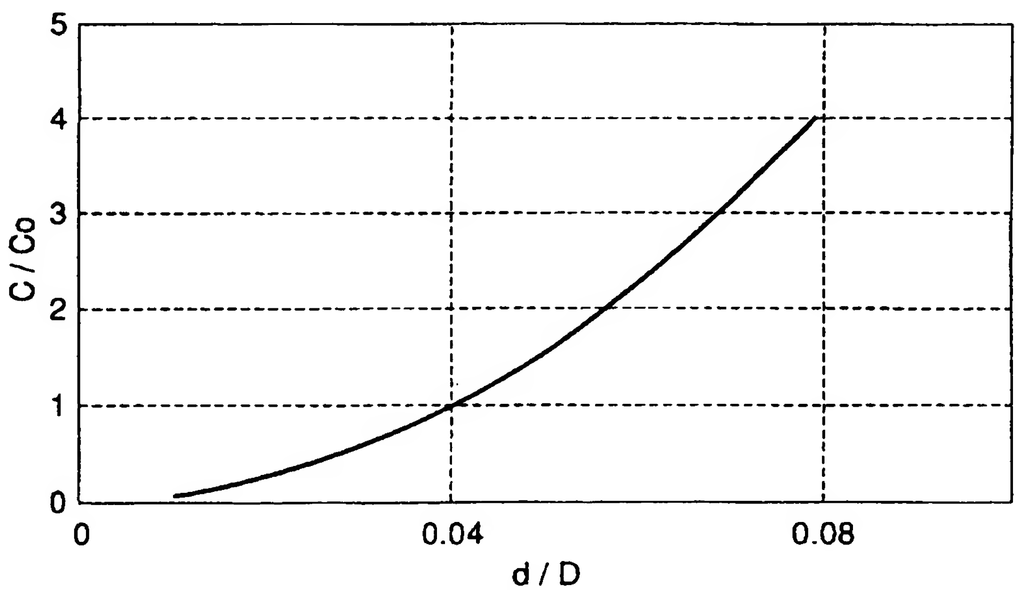
FIG.1



【図2】
FIG.2

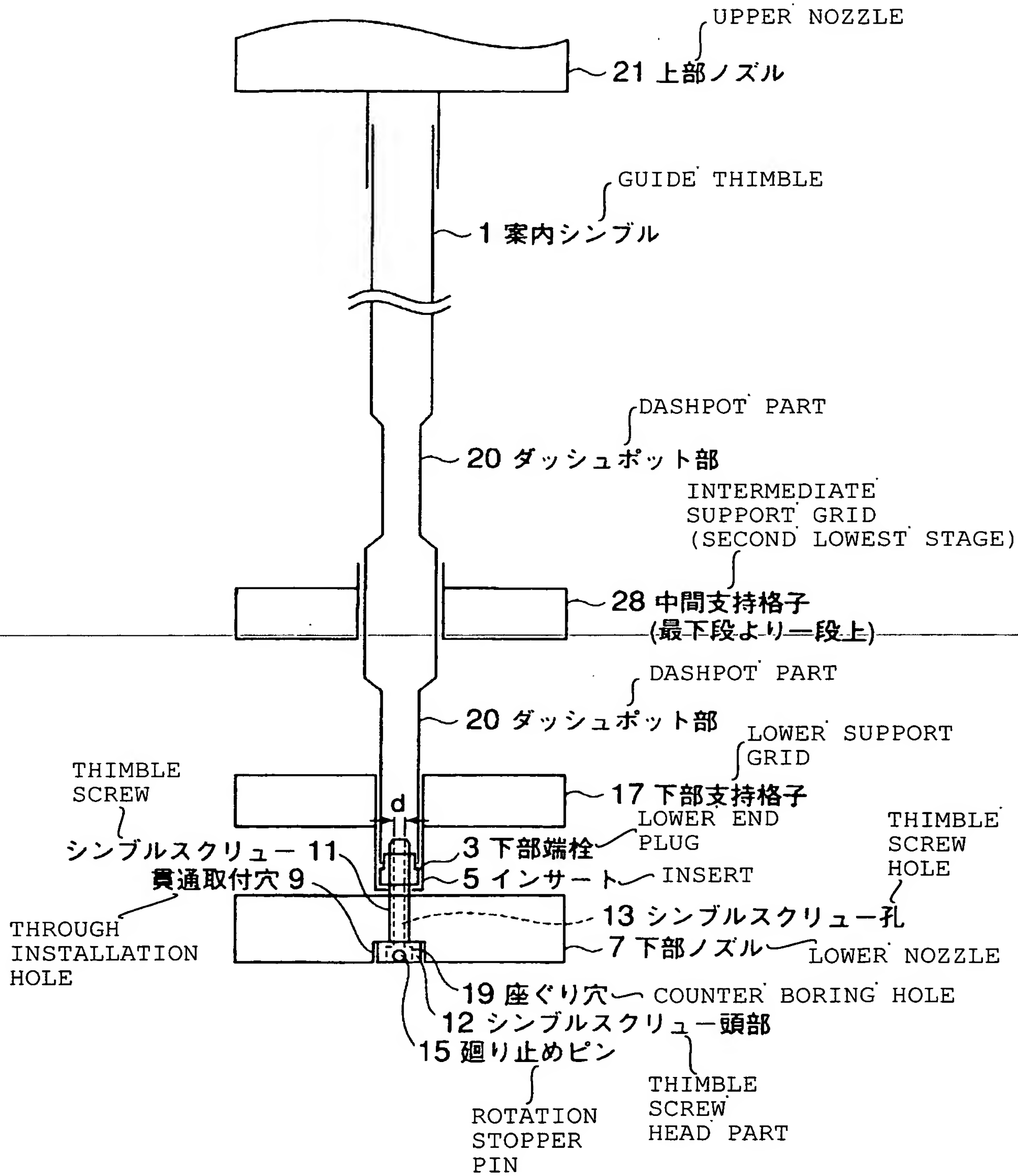


【図3】
FIG.3



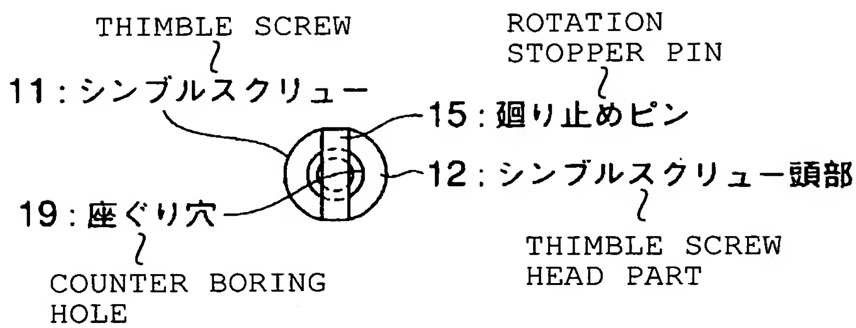
【図４】

FIG.4

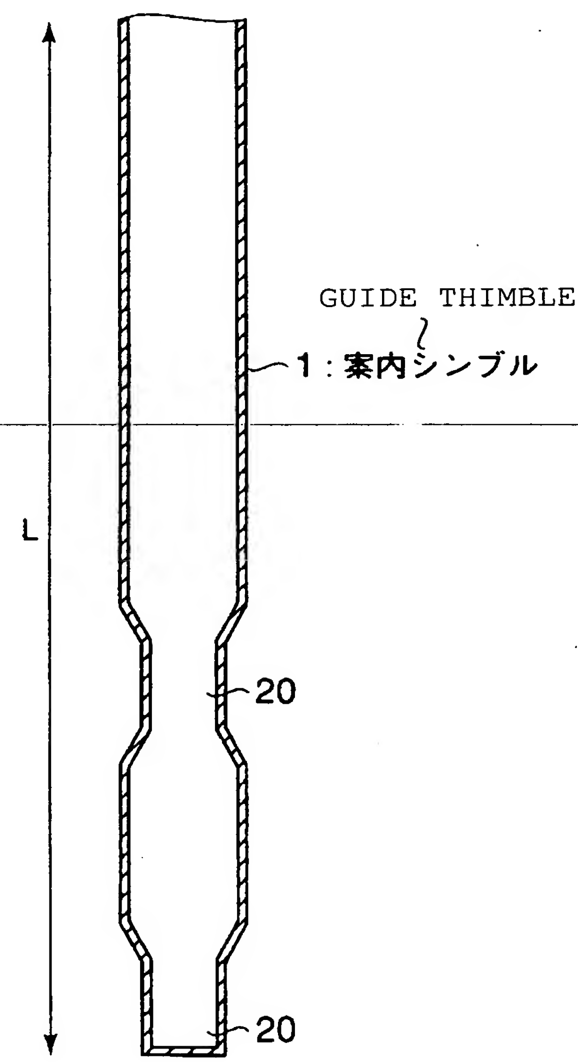


UPPER NOZZLE
21 上部ノズル
GUIDE THIMBLE
1 案内シンブル
DASHPOT PART
20 ダッシュポット部
INTERMEDIATE SUPPORT GRID (SECOND LOWEST STAGE)
28 中間支持格子
(最下段より一段上)
DASHPOT PART
20 ダッシュポット部
LOWER SUPPORT GRID
17 下部支持格子
THIMBLE SCREW
シンブルスクリュー 11
d
3 下部端栓
LOWER END PLUG
貫通取付穴 9
5 インサート
INSERT
THIMBLE SCREW HOLE
THROUGH INSTALLATION HOLE
13 シンブルスクリュー孔
7 下部ノズル
LOWER NOZZLE
19 座ぐり穴
COUNTER BORING HOLE
12 シンブルスクリュー頭部
15 廻り止めピン
THIMBLE SCREW HEAD PART
ROTATION STOPPER PIN

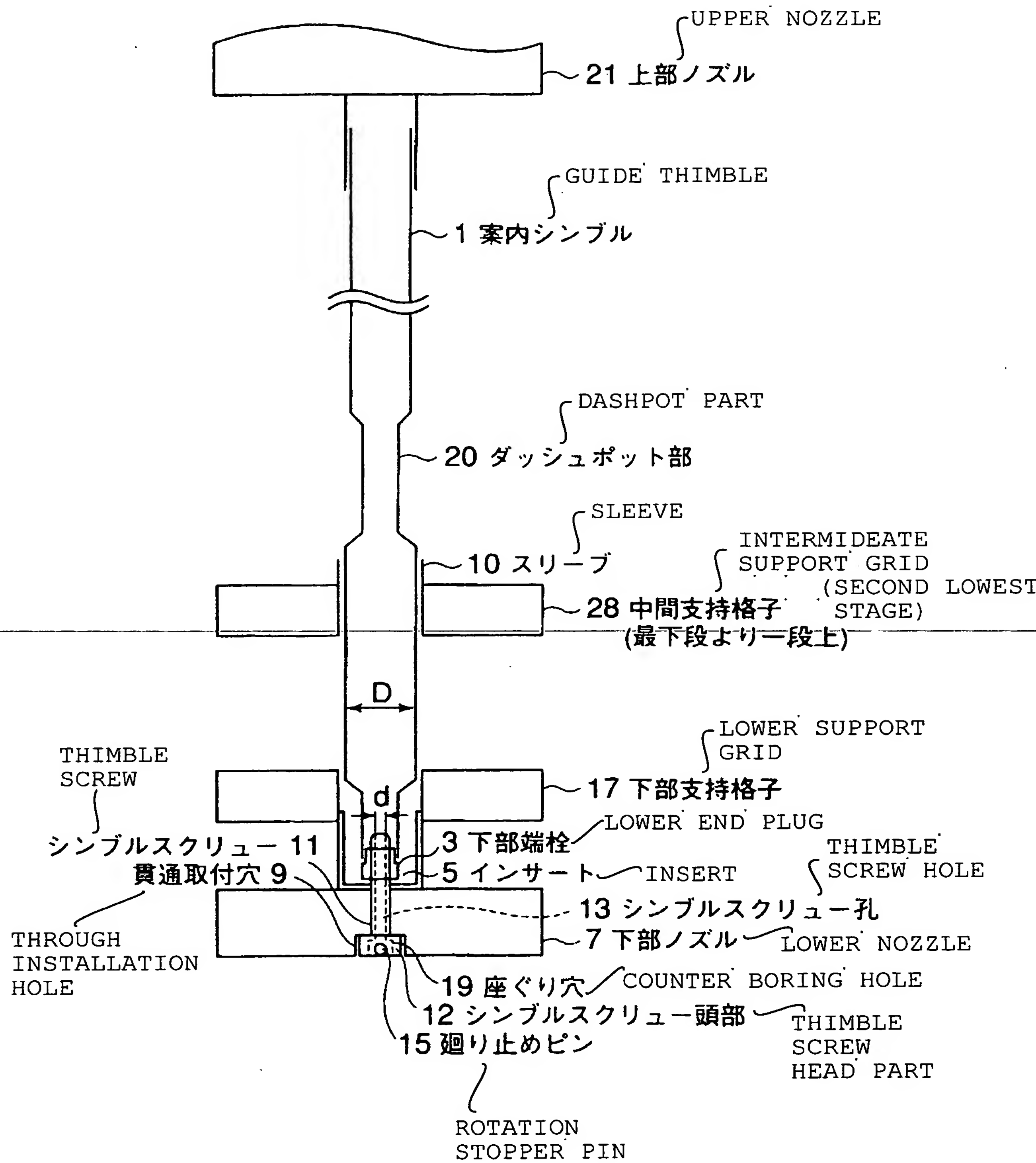
【図5】
FIG.5



【図6】
FIG.6



【図７】
FIG.7



UPPER NOZZLE
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LOWER NOZZLE
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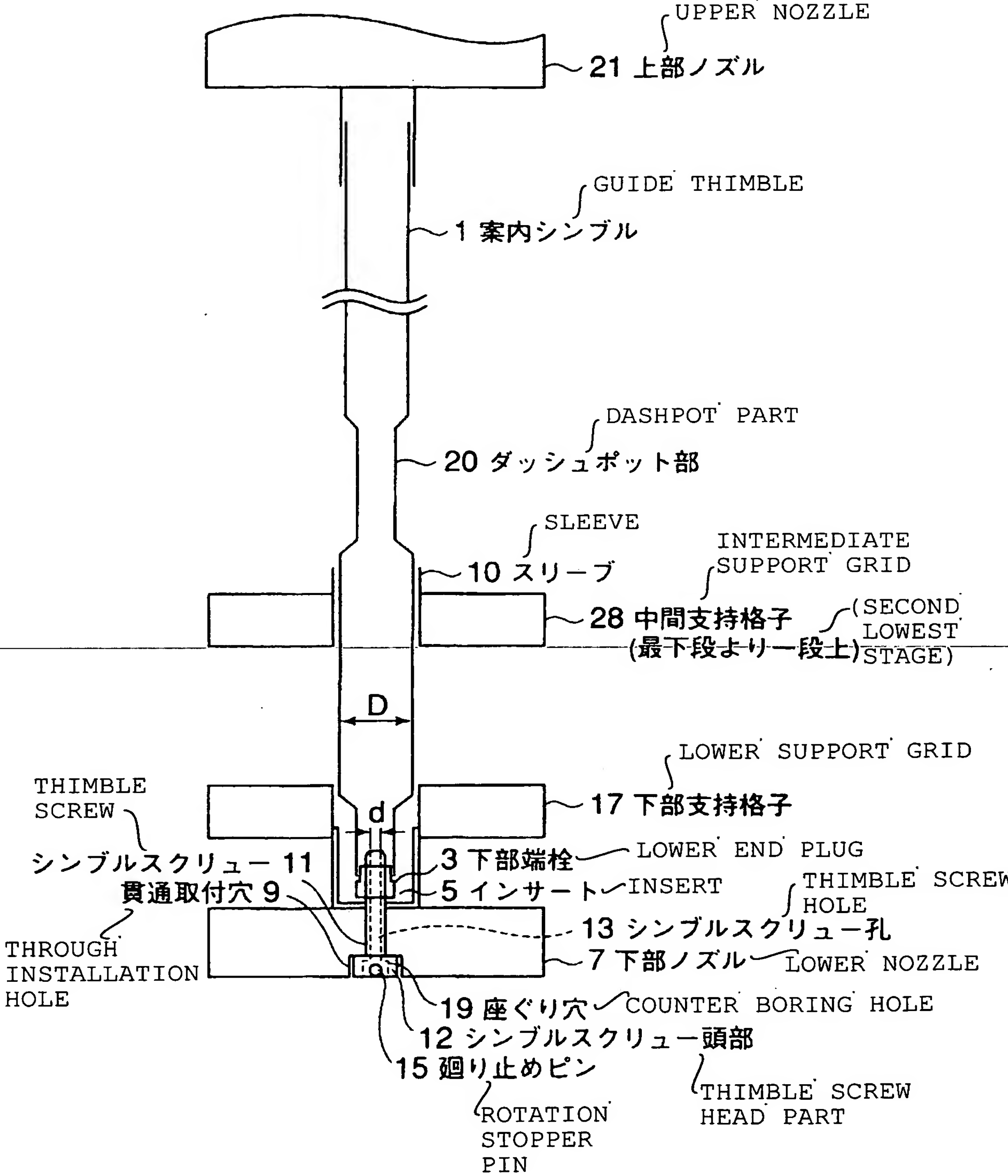
COUNTER BORING HOLE
12 シンブルスクリュー頭部
THIMBLE SCREW HEAD PART
15 廻り止めピン
ROTATION STOPPER PIN

【図８】
FIG.8


UPPER NOZZLE
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ROTATION STOPPER PIN

[Document] Abstract

[Abstract]

[Object] A fall impact produced when a control rod falls is moderated, and flexural deformation of a dashpot is prevented, without impairing the cooling function of non fuel bearing components.

[Means for Achieving the Object] Comprised are a lower nozzle 7 set on a lower core plate of PWR, an upper nozzle 21 with a press spring 22 to urge the lower nozzle 7 against the lower core plate, a plurality of guide thimbles 1 which guide control rods, having passed through the top nozzle 21, toward the lower core plate, a plurality of support grids 27, 28, and 17 mounted on each of guide thimbles 1, a plurality of fuel rods 26 held by the support grids 27, 28, and 17 to be substantially parallel to the guide thimbles, a thin tube-like dashpot part 20 formed on each of the guide thimbles 1 to reduce a fall velocity of a corresponding one of the control rods, a thimble screw 11 which connects the guide thimbles 1 to the lower nozzle, and a thimble screw hole 13 formed to extend through the thimble screw 11, wherein the dashpot part 20 has a large-diameter portion, at a lower portion thereof, with substantially the same diameter as that of each of the guide thimbles, and a hole diameter d of the thimble screw hole falls within a range of $0.04D < d < 0.08D$ where D is an inner diameter of the large-diameter portion.

[Elected Figure] FIG. 7